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SHORT COMMUNICATION

Root structure of slope protection plants in a high-grade highway

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Abstract: Root length and root length density of *Lespedeza bicolor*, *Amorpha fruticosa*, and Sea buckthorn were investigated in a country highway-TongSan highway (Tongjiang to Sanya) in Heilongjiang Province, China. The root lengths were divided into five root orders according to Pregizter sequence classification method. Results show that sea buckthorn roots are dominated by coarse roots in the horizontal growth, while *L. bicolor* has a large proportion of fine roots in vertical conical growth and *A. fruticosa* is in depth growth. Root length density of *L. bicolor* in all the root sequences is higher than that of sea buckthorn and *A. fruticosa*. On the basis of the root structure, it is inferred that *L. bicolor* roots mainly absorb the surface soil moisture for its normal growth; in contrast, *A. fruticosa* has good uptake ability to deep soil water. The root structure of sea buckthorn implies that it has a strong drought resistance.

Keywords: seasonal frost area; slope protection plant; root structure

Introduction

Root distribution in soil is an important factor affecting the capacity of plant to absorb nutrients and water (Zhou 1994). Research on plant roots began in the early 18th century (Bŏhm 1979). For example, Cannon (1911) revealed the variability of taproot and lateral roots of desert plants. Currently the term "root architecture" is widely used in the field of root systems. Root architecture is the spatial configuration and distribution of various roots (Lynch 1995). Root architecture includes three-dimensional geometry and plane geometry configuration. The three-dimensional geometry configuration is the three-dimensional distribution of the different types of roots (straight root) in the same roots or adventitious root (fibrous root) in the growth medium (Yan and Zhang1997). Plane geometry configuration is the distribution of various roots in the same root axis along the two-dimensional plane. Root structure is regarded as a decisive factor for plant uptake function. Root geometry configuration determined the role of plant in soil fixation and soil erosion (Coutts 1983; 1987). Thus, it is necessary to investigate root architecture of different plants and find healthy and stable root architecture.

Plants play an important role in improving the slope stability (John and Sons 1987; Gray and Sotir 1996; Coppin and Richards 1990; Morgan and Rickson 1995). Shrubs and herbs are the common slope protection plants in high grade highways. *Amorpha fruticosa*, *Lespedeza bicolor* and sea buckthornua are the popular local slope protection plants in the Northern China (Xiong et al. 2004; Chen et al. 2009; Zhang and Li 2010), which all have strong resistance and adaptability. In the present study, the root distribution of *A. fruticosa*, *L. bicolor* and sea buckthorn was investigated in the slope soil of a high grade highway to explore the slope protection mechanism of plants.

Materials and methods

Study sites

In this study, the sampling sites are located at 50−100 m away from Hatong toll station in the highway from Harbin to Tongjiang, which is a highway of northern high-latitude and seasonal frost area. Ha-Tong highway is one part of the country highway-TongSan highway (Tongjiang to Sanya) in Heilongjiang Province, China. The protection technologies for the highway consist of plant protection technology and engineering one. The engineering protection technology includes infiltration technology, anti-sliding block walls slope protection technology and reinforced concrete frame. While the plant slope technology includes three-dimensional vegetation net slope protection technology, lawn seeding planting techniques, and tree planting slope revetment techniques.

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Sampling

Root samples of fine *L. bicolor*, *A. fruticosa*, and sea buckthorn plants were obtained by hand-dig method to obtain the overall structure of root systems and to maximize the integrity of fine roots. To ensure the integrity of root system, the diameters of the basal stems were measured firstly, and then a complete Apple-type soil lump in the radius of 10 times the stem was digged.

Test methods

Features of roots distribution and the test of live biomass

According to the distribution of living roots, the root growth and root lengths in the soil depth of 0–100 cm were measured. All the standard strains of each root system were obtained at an interval of 20-cm soil layer, washing the root samples in the laboratory, drying and then weighing root biomass.

Test of root parameter

A total of nine samples were selected in a plot of 20 m × 30 m, three individuals for each tree species. The samples were taken in July 2007 for obtaining relatively complete root systems. Each sample point was divided into layer A (0–10 cm) and B (11–20 cm). For each soil layer, a soil column of 20 cm × 20 cm × 10 cm was taken to the laboratory, and then soil particles and impurities associated with the roots were washed off with deionized water of 2–3°C. The grade of the root sequence was distinguished on the petri dish with the diameter of 15 cm based on Pregizter sequence classification methods. The number of the root sequence for each grade, the average root length, root density were recorded.

Results and analysis

Root distribution

The characteristics of root distribution of *A. fruticosa*, *L. bicolor*, and Sea buckthorn are shown in Fig. 1. Coarse roots of sea buckthorn were mainly distributed in the soil layer of 1–60 cm, whereas coarse roots of *A. fruticosa* were distributed in the 0–100 cm soil layer. In the soil layer of 21–40 cm, the total coarse root length of *L. bicolor* is the maximum among the three species.

Roots of *L. bicolor* were mainly distributed in the soil layer of 0–40 cm, accounting for 87.6% of total root biomass (Table 1). Root biomass of *A. fruticosa* was concentrated in the soil layer of 41–60 cm, and the fine root biomass is the maximum in 61–80 cm soil layer. For sea buckthorn, coarse roots are the dominant roots, and the fine root biomass is higher in 20–40 cm soil layer than in other layers,

Average root length

The root length of *A. fruticosa*, *L. bicolor*, and sea buckthorn can be divided into five root orders based on Pregizter sequence classification method as shown in Table 2. For *A. fruticosa*, sea buckthorn, and *L. bicolor*, fine root lengths showed an increasing trend from the first root order to fifth root order. In the same root order, the fine root lengths of 1,2,3-class roots are more close among the species; however, the average root length of the 4- and 5-class roots (as the lateral root and main root, respectively) have a big difference, of which the root length of *A. fruticosa* is the largest and *L. bicolor* the smallest.

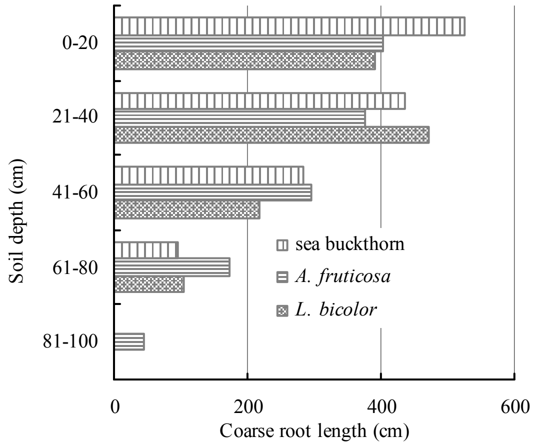

Fig. 1 Total coarse root length of *A. fruticosa*, *L. bicolor*, and sea buckthorn in different soil layers.

Table 1. Distribution of root biomass in different soil layers

Soil depth (cm)	Root biomass (g)					
	Percentage of root biomass levels			Percentage of fine-root biomass		
	Sea Buckthorn	*A. fruticosa*	*L. bicolor*	Sea Buckthorn	*A. fruticosa*	*L. bicolor*
0-20	37.1	26.2	40.1	1.7	0.8	13.7
21-40	52.8	31.3	47.5	4.2	2.7	29.6
41-60	8.7	34.8	10.3	7.8	17.6	32.6
61-80	1.4	6.9	2.1	1.5	19.7	0
81-100	0	0.8	0	0	1.2	0

Table 2. The average length of all levels of the root order of Sea buckthorn, *A. fruticosa* and *L. bicolor*

Species	Root length in different root orders				
	First order	Second order	Third order	Fourth order	Fifth order
Sea Buckthorn	5.53mm	9.23mm	18.22mm	22.53mm	37.34mm
A. fruticosa	8.25mm	14.36mm	21.09mm	29.29mm	46.75mm
L. bicolor	9.05mm	11.95mm	12.82mm	20.54mm	26.33mm

Root length density

Root length density (Root Length Density, RLD), the total length of fine roots (cm/cm^3) in per unit of soil, is the important basis to estimate roots absorbing water and nutrients. Root length density,

to some extent, represents the root absorption surface area in the unit of soil. The greater RDL, the larger root absorption surface area is. As shown in Fig. 2, in the surface soil and sub-surface soil, root length density of all the three tree species showed a decreasing trend with the change of root sequences from low order to high order. The root length density of *L. bicolor* is the largest, followed by Sea Buckthorn and *A. fruticosa*. For all the five root orders, the root length density in the surface soil (0–10 cm) is larger than that in the sub-surface soil (11−20 cm). This trend is consistent with the change of average length. It implies that root nutrient absorption is mainly focused on the surface soil.

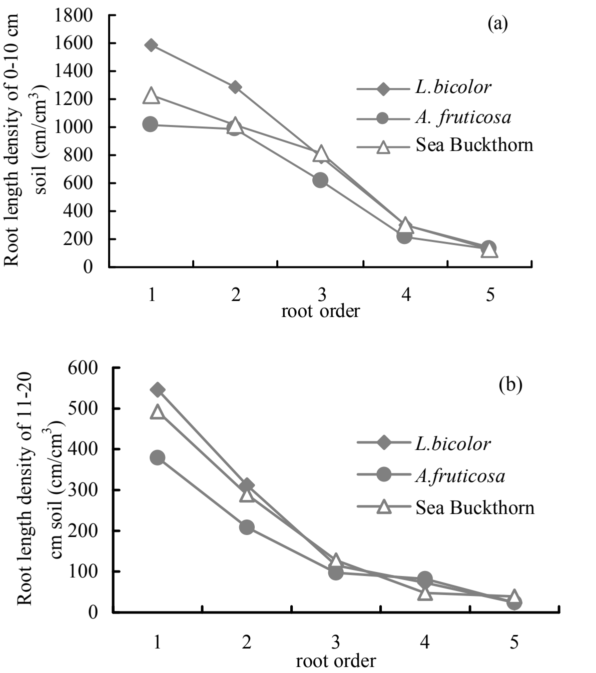

Fig. 2 Root length density of different root orders in the soil layers of 0−10 cm (a) and 11−20 cm (b)

Conclusion

Root structure analysis shows that *A. fruticosa* roots are dominated by the roots of vertical growth, including the main roots, lateral roots and fibrous roots. In contrast, *L. bicolor* has short and thick dense root systems. For Sea Buckthorn, coarse roots of vertical and horizontal growth are the dominant roots; lateral roots and fine roots show vine growth, with a large lateral root area. Thus Sea buckthorn roots show drought-resistant root system morphology and would have the ability to use deep soil moisture. The average root length of fine roots are similar among the three tree species; however the root length density of *L. bicolor* is the largest, followed by sea buckthorn and *A. fruticosa*. This indicates that *L. bicolor* has a better ability to absorb water and fertilizer than *A. fruticosa* and sea buckthorn.

References

Bŏhm W. 1979. *Methods of Studying Root Systems*. Berlin, New York: Springer-Verlag, p188.

Chen Xueping, Zhang Hongjiang, Zhang Xiang, Jiang Yulin, Li Haifen, Cao Chuanlin. 2009. Plant Selection for Highway Slope. In: Proceedings of *National Highway Ecological Green Theory and Technology,* pp. 277−287. (In Chinese)

Coppin N J, Richards IG. 1990. *Use of Vegetation in Civil Engineering*. London: Butterworths, p292.

Coutts MP. 1983. Root architecture and tree stability. *Plant Soil*, **71**: 171−188.

Coutts MP. 1987. Developmental processes in tree root systems. *Can J For Res,***17**: 761−767.

Greenway DR. 1987. Vegetation and slope stability. In: *Slope Stability*. New York: John Wiley and Sons, pp.187–230.

Gray DH, Sotir RB. 1996. *Biotechnical and soil bioengineering slop stabilization: A practical guide for erosion control*. John Wiley and & Sons.ISBN:0-471-04978-6.

Lynch JP. 1995. Root architecture and pant productivities. *Plant Physiol*, **109**: 7−13.

Morgan RPC, Rickson RJ. 1995. Slope Stabilization and Erosion Control: A bioengineering approach. London: E & FN Spon, pp. 221−264.

Xiong Bingquan,Yu Dong,Yuan Jun, Zeng Ming, Zhang Yong, Du Jianbin. 2004. Sea buckthorm plant resources and utilization. *Chinese Wild Plant Resources,* **4**: 25−26. (In Chinese)

Yan Xiaolong, Zhang Fusuo. 1997. Genetics of Plant Nutrition. Beijing: China Agriculture Press, pp.78−197.

Zhang Jun, Li Jinlong. 2010. Application & cultivation techniques of Amorpha canescens on highway greening. *Protection Forest Science and Technology*, (1): 121−122. (In Chinese)

Zhou Xiaofeng. 1994. *China Location of Forest Ecosystems*. Harbin: Northeast Forestry University Press, pp.517−523.(In Chinese)